LEATHERHEAD
FOOD R.A.

HYGIENIC PUMPS FOR FOOD MANUFACTURE

R. DARLINGTON, B.Sc.

SCIENTIFIC & TECHNICAL SURVEYS No. 111

JUNE, 1979

THE BRITISH FOOD MANUFACTURING INDUSTRIES RESEARCH ASSOCIATION

SCIENTIFIC AND TECHNICAL SURVEYS

Number 111 June, 1979

Hygienic Pumps for Food Manufacture

R. Darlington, B.Sc.

CONTENTS

FOREWORD

This *Scientific & Technical Survey* is based on a project undertaken for the Department of Industry – Mechanical Engineering and Machine Tools Requirements Board and which was reported to the above in April, 1979. The results of the research reported herein are the property of the Department of Industry and are Crown Copyright © 1979.

SUMMARY

Many food manufacturers have problems with positive displacement pumps used in food production processes. Several food companies have been visited to discuss the mechanical and process difficulties they have experienced using the many proprietary positive pumps currently available.

Brief descriptions of pump types together with their advantages and disadvantages are given. Cleaning methods and procedures for assessing cleanability are also included.

A specification for an ideal positive displacement pump or transfer system is given based on comments received from production managers, microbiologists, mechanical and process engineers working in the food industry.

It is recommended that the Food R.A. contact pump manufacturers to discuss the design of a new pump or transfer system to meet the food process engineers' requirements.

RÉSUMÉ

Beaucoup de fabricants de produits alimentaires ont encontré des difficultés avec les pompes volumétriques utilisées dans les divers procédés de production. Plusieurs établissements ont été visités pour discuter des problèmes mécaniques et industriels posés par l'utilisation de la grande diversité de pompes volumétriques disponibles aujourd'hui.

Des descriptions abrégées des types de pompe sont données avec leurs avantages et leurs inconvénients. Les méthodes de nettoyage et les procédures utilisées pour évaluer la nettoyabilité sont incluses aussi.

Une spécification définissant la pompe volumétrique ou le système de transfert idéal est joints à l'étude. Cette spécification est basée sur les observations faites par des chefs de production, des microbiologistes, des ingénieurs mécaniciens et des ingénieurs des procédés de transformation employés dans l'industrie alimentaire.

Il est recommandé que la Food R.A. se mette en contact avec les fabricants de pompes pour discuter la mise à l'étude d'un nouveau type de pompe volumétrique ou de système de transfert basé sur les exigences formulées par les ingénieurs des procédés de transformation des produits alimentaires.

ZUSAMMENFASSUNG

Viele Nahrungsmittelhersteller haben Probleme mit den Verdrängerpumpen, die in dem Verfahren der Nahrungsmittelherstellung angewendet werden. Es sind verschiedene Nahrungsmittelfirmen besucht worden, um die maschinellen und Verfahrensschwierigkeiten, auf die sie mit der Anwendung der vielen, gegenwärtig erhältlichen Marken von Verdrängerpumpen gestoßen sind, zu diskutieren.

Es werden kurze Beschreibungen der Pumpenarten zusammen mit ihren Vor- und Nachteilen gegeben. Reinigungsmethoden und Verfahren, mit denen die leichte Sauberhaltung beurteilt wird, sind mit inbegriffen.

Es wird eine auf kritischen Anmerkungen beruhende Spezifizierung für eine ideale Verdrängerpumpe oden ein Transfersystem gegeben, die von den in der Nahrungsmittelindustrie arbeitenden Produktionsmanagern, Mikrobiologen, Maschinenbau- und Verfahrensingenieuren entgegengenommen wurde.

Es wird empfohlen, daß sich die Nahrungsmittel — R.A. mit den Pumpenherstellern in Verbindung setzt, um die Konstruktion einer neuen Pumpe oder eines Transfersystems, das den Anforderungen des Ingenieurs in der Nahrungsmittelverarbeitung entspricht, zu diskutieren.

INTRODUCTION

Many types of positive displacement pumps are available to the food industry. Their unique constructional and operational features have been examined. Listed below are the various pump types, some of which have advantages over others for a particular pumping duty:

1. Piston and plunger
2. External and internal gear
3. Lobe
4. Vane
5. Screw
6. Diaphragm
7. Peristaltic

The Food Manufacturers Federation (FMF) and the Food Machinery Association (FMA) Joint Technical Committee issued a brief code of practice on hygienic design for pumps, pipelines, valves and vessels in 1969[1]. They also issued guidelines specifically for use in hygienic pump design[2]. Many pump manufacturers adhere closely to these recommendations. They design and manufacture pumps taking care to incorporate the special hygienic features. Pump manufacturers' brochures usually include information which lists all the advantages for a particular pumping duty; this information makes pump selection easy in most cases. Pump salesmen also help the purchaser to choose the best available pump for the job. The buyer, of course, has the final word: he chooses the most suitable pump based on information received and his own experience.

Food process engineers use pumps to transport food products from one place to another. A pump overcomes frictional losses due to product flow in pipework; it may also be used to convey materials from one level to another.

A pump, after cleaning, must not contaminate the next product pumped. Retained dirt, debris, product and micro-organisms above the accepted specification should be removed. Careful attention to hygienic design allows the cleaning fluids to remove or destroy the contaminants.

Manual and in-place cleaning methods are used. Many food manufacturers still have problems with positive displacement pumps used in food production processes.

The project objective was to identify these problem areas and ultimately to design, in conjunction with a pump manufacturer, a new positive displacement device which will be more reliable, easier to maintain, easier to clean, disinfect or sterilise than those currently marketed.

Six major food manufacturing companies have been visited to discuss the problems they have experienced using the many proprietary positive pumps currently available. These companies use pumps purchased from sixteen pump manufacturers. The pumping duties cover a wide range of food products which is considered representative of the food industry as a whole. Mechanical and process problems have been identified and listed. Cleaning methods and procedures for assessing cleanability have also been noted.

POSITIVE DISPLACEMENT PUMP SELECTION

The following criteria are used in pump selection:

(a) Nature of the product
(b) Process requirements
(c) Hygienic requirements

Nature of the Product

The following product information is essential before pump selection can be made.

1. *Product viscosity*

For a Newtonian liquid the coefficient of viscosity η is the factor of proportionality between the shear stress τ and the shear rate D where $\tau = \eta D$.

For many food products this factor does not remain constant. These materials are classified as non-Newtonian fluids where the ratio of the shear stress to the shear rate is the apparent viscosity corresponding to a particular shear rate.

For pseudoplastic materials an increase in shear rate leads to a decrease in apparent viscosity. When the apparent viscosity continues to decrease during the time for which the shear rate is applied, the material is said to be thixotropic. For dilatant liquids, an increase in shear rate leads to an increase in apparent viscosity. When the apparent viscosity continues to increase with the time for which the shear rate is applied, the material is said to be rheopectic. Pseudoplastic and dilatant liquids immediately return to their original state when the shear is removed. Thixotropic and rheopectic liquids also return to their original state when the shear is removed, but in this case there may be a time delay that varies over wide ranges for different liquids.

The rate of flow of some materials increases sharply at a certain yield stress. These fluids are commonly referred to as Bingham plastics. Below this yield stress the substance is almost rigid and retains its shape against gravity for long periods. These materials do not drain easily from plants under gravity.

A positive displacement pump may be the only pump capable of meeting the desired pumping duty if the viscosity is too high for other types of pump.

The higher the viscosity the greater the head losses due to friction in the pipeline and the pump. The power required for pumping also increases with an increase in fluid viscosity. Almost all types of positive pumps are suitable for viscous materials. For very viscous products, piston, plunger and flexible vane pumps have limited application.

2. *Product density*

The density is defined as weight per unit volume. Specific gravity of liquid and solids is the density compared with that of water at 4°C. Many pump manufacturers give pump throughputs on a volume basis, and the density is used to convert this figure to a weight basis provided of course the fluid is incompressible (i.e. contains no air or gas). The specific gravity of most food products is between 0.8 to 2.0.

3. *Solids content and nature of solids*

Food products can contain suspended solids or dissolved solids or both. The presence of hard gritty abrasive particles can cause wear in the pump particularly on the moving parts. The diaphragm and the peristaltic pumps, and in limited applications the screw pump, are probably the best pumps for abrasive materials. A pump is often run at low speeds when abrasive materials are present in an attempt to prolong pump life. Process materials having lubricating properties reduce wear. Suspended solids can also lead to blockage within the pump. The maximum size of suspended solid encountered in the food industry is usually of the order of 2.0×10^{-2} m cube. Pumps must have a large clearance volume to accommodate particles of this size.

4. Entrained gases

The presence of entrained air or gas in the process material causes a reduction in throughput expressed as weight per unit time.

Process Requirements

The pumping duty required and the operating conditions must be known before pump selection is made.

1. Capacity

The pump throughput may be constant or variable. In the latter case positive displacement pumps need speed control units fitted. Many people define a positive displacement pump as a pump which will generate a substantially constant discharge at any particular speed regardless of the head. In practice, however, this is not true. To generate high heads efficiently such pumps must be designed appropriately. Single piston or plunger, diaphragm and some types of lobe pump have a pulsed discharge and they should not be used in process lines requiring a steady product flow unless a pulse damping device is used. It may be prudent to install an oversized pump initially if an increase in capacity is required in the future.

The capacity is affected by internal product leakage which occurs between the discharge and suction side of the pump. This leakage is commonly referred to as slip. The leakage depends on the width and shape of the pump clearances, the product viscosity, and the pressure difference between the discharge and suction of the pump. Provided the internal parts of the pump do not distort with increasing back pressure the slip increases linearly with the pressure difference across the pump if the pumped liquid is in laminar flow. For turbulent flow, slip increases with the square root of the pressure difference across the pump.

Leakage can also occur through packing glands on shafts, piston and plunger seals and defective diaphragms. If the leakage is excessive a substantial reduction in capacity can occur. Air ingress through shaft seals also reduces the pumping rate. High capacities can be achieved using the piston and screw type of pump.

2. Suction conditions

A pump may have to operate under a suction lift condition. To work effectively the pump must be capable of generating this lift on the suction side. Where a pump with poor suction lift capabilities is preferred for other reasons it may be necessary to install the pump at liquid level or below so that it operates on flooded suction. Pumps must be completely filled with material being pumped to achieve smooth operation, otherwise a loss in capacity results. This may occur when some of the product vaporises in the suction line or pump chamber. The vapour bubbles are carried into high pressure regions of the pump where they collapse resulting in noise and vibration. This phenomenon is called cavitation. Cavitation can also occur from air ingress through the pump seals. The repeated blows of the collapsing bubbles cause rapid wear and may also accelerate the corrosion rate. Pitting of pump components is a common result of cavitation. The greater the slip in a pump the smaller the effect of cavitation. Cavitation is usually more serious with viscous liquid than with thin liquids. High-speed pumps are more prone to cavitation than low-speed pumps.

In a leak-free pump, cavitation can be avoided by ensuring that the available head in the suction line is always greater than that required by the pump. Short suction lines of large diameter will reduce the frictional head loss and increase the available suction head. Wide bore entry throats may be needed on pumps used to transport very viscous materials.

When not in use, pumps and suction lines may be full of air which must be removed before the pump can convey material. Normally positive displacement pumps are self-priming although priming may be required where there are high suction lifts. Priming may be carried out either by displacing the air in the suction line with product or by drawing out the air by means of a vacuum pump.

3. Discharge conditions

The discharge conditions govern the head or back pressure against which the pump works, and thus the fluid pressure generated within the pump. Under no circumstances must a positive displacement pump be operated against a closed discharge. This discharge pressure will increase and could result in serious damage to the pump. To guard against this, pumps are often fitted with bursting discs, pressure relief valves or a motor overload protection device.

The outlet pipework is designed in such a manner that the pump manufacturer's recommended maximum operating discharge pressure is not exceeded.

4. Temperature of operation

The majority of positive displacement pumps currently in use have to operate at a temperature within the range ambient to 90°C. The clearances between the case or stator and the rotor must accommodate the expansion of the components without seizure. Sterilisation temperatures of up to 150°C may be required and the clearances between the moving parts might be so large that the pump may not be able to pump the cleaning fluids at the correct rate. Usually the life of packing, glands, diaphragms, piston and plunger seals is considerably reduced as the temperature rises above 100°C.

Hygienic Requirements

In 1969, the Food Manufacturers' Federation (FMF) and the Food Machinery Association's (FMA) Joint Technical Committee produced a brief code of practice related to hygienic design for pumps, pipelines, valves, tanks and vessels[1] (see Appendix I). The FMF and FMA also issued guidelines specifically for use in hygienic pump design[2] (see Appendix II). Many pump manufacturers adhere closely to these recommendations. They design and manufactur pumps taking care to incorporate the special hygienic features. A pump must be chosen which will either remain clean during its normal operation or be such that cleaning will enable it to be restored to the desired degree of cleanliness. These are degrees in hygienic requirements generally related to the permitted tolerance of microbial contamination of the final product. Often completely aseptic operation is not practicable, though in some cases it would be desirable.

The hygienic requirements for the pump should not be considered in isolation from the rest of the plant. The compatibility of the equipment with the product, the environment and also the cleaning fluids is of vital importance.

DESCRIPTION OF PUMP TYPES

1. Piston and Plunger Pumps (see Figs 1, 2 and 3, Appendix III)

Piston and plunger pumps operate in almost the same manner. They differ in that the plunger moves through a stationary packed seal whereas in piston pumps, the seal is carried by the piston. A plunger pump can be used for operation at higher pressure than a piston pump. The piston or plunger moves in a reciprocating cycle. On the suction stroke product enters the cylinder through a one-way valve. On the pressure stroke the product is forced through a one-way valve into the discharge line.

Advantages

1. These pumps are capable of developing high discharge pressures (i.e. piston pumps up to 15,000 psig (1.03×10^8 N/m^2), plunger pumps up to 20,000 psig (1.37×10^8 N/m^2)).

2. High throughputs are possible using multi-cylinder piston pumps.

3. Piston and plunger pumps are excellent for accurate metering of products.

Disadvantages

1. These pumps are usually heavy and cumbersome.

2. They are not particularly good for very viscous materials and are unsuitable for products containing abrasive solids.

3. They are not usually used for pumping pastes, greases, pulps and shear-sensitive food products.

4. The discharge from a single cylinder pump pulsates. However, a more even flow is possible using double-acting or multiple cylinders.

5. Usually these pumps are difficult to dismantle and clean.

2. Gear Pumps

External gear pumps (see Fig. 4, Appendix III)

This pump has a casing containing two meshing gears of equal size. These gears may be of the spur, helical or double-helical (herringbone) types. One of the gears is coupled to the drive shaft which transmits the power from the motor. Usually the other gear runs free but for severe service both pumping gears are driven by timing gears. A partial vacuum is created by the unmeshing of the rotating gears. This induces the process material to flow into the pump. The pockets of product are carried to the outlet side of the pump between the rotating gear teeth and the fixed casing where the meshing of the rotating gears prevents the return of the material to the feed or suction side of the pump.

Internal gear pumps (see Fig. 5, Appendix III)

The drive shaft is coupled to a rotor which has internally cut gear teeth. These mesh with the teeth of an externally cut idler gear. The idler gear is set off centre from the rotor. As the rotor turns, a partial vacuum is induced by the unmeshing of the internal teeth of the rotor and the external teeth of the idler. This causes material to flow into the pump. Product is carried to the discharge between the teeth of both the rotor and idler and the fixed casing.

Advantages

1. These pumps are self-priming.

2. They give a constant delivery for a set rotor speed.

3. No check valves are required.

4. Pumping in either direction is possible.

5. Materials containing vapours and gases can be pumped.

6. Manual cleaning is relatively easy once they are dismantled.

7. Internal gear pumps are usually run at lower rotational speeds. This reduces friction, wear, and turbulence. They are more suitable for shear-sensitive products.

Disadvantages

1. The products pumped must be free from hard solid particles.

2. The pump cannot operate against a closed discharge without causing serious damage; hence pressure relief valves are needed or the drive unit must be fitted with an overload cut-out facility.

3. Close clearances between the moving parts are essential so alignment is critical. Skilled personnel are needed to dismantle and re-assemble for maintenance and manual cleaning

4. These pumps depend on the products pumped to lubricate the internal moving parts. Damage can occur if they are allowed to run dry.

5. Shaft seals are required. Product leakage through the seals can occur. Air may be drawn in through the seals reducing pumping efficiency.

6. Variable speed drives are often needed to provide changes in pumping rate. These tend to be rather expensive.

3. Lobe Pumps (see Figs 6 and 7, Appendix III)

These pumps operate in a similar manner to external gear pumps. Instead of having gear wheels the lobe pump has two impellors with two, three or four lobes on each. The impellors are driven independently and usually a small clearance is maintained between them.

Advantages

The advantages are the same as for external gear pumps with the following exceptions:

1. Alignment, on assembly, is not so critical as for gear pumps.

2. Wear is generally less. Replaceable packing strips can be fitted on the lobe ends to protect them from wear.

3. Lobe pumps are in general easier to clean.

4. There are a number of lobe rotor forms available enabling the design to be 'tailored' to pump a wide variety of products (e.g. 'D' rotor).

5. Besides stainless steel, rotors can be made using other food quality materials (e.g. rubbers, plastics) which give improved operating efficiency and less wear and also extend the range of operating temperature.

Disadvantages

The disadvantages are the same as for the external gear pumps with the following exceptions

1. The output from lobe pumps pulsates more than that from gear pumps. The greater the number of lobes however the less the pulsation.

2. Some lobe materials transfer taint, picked up from the cleaning fluids, to the product.

3. Slip increases as the number of lobes decreases.

4. Vane Pumps (see Figs 8, 9 and 10, Appendix III)

There are two basic types of vane pumps: (a) sliding vane, where the vanes are housed in slots in the rotor and can extend in a radial direction; (b) swinging vane pump, where the vanes are hinged to the rotor and swing outwards under centrifugal force.

Both rely on the same basic mechanical action of producing variable inter-vane volume during rotation by mounting the rotor eccentrically to the casing. The eccentricity of the revolving rotor produces a partial vacuum at the suction or inlet side of the pump causing an inflow of process material. This is carried to the discharge side of the pump in the space between the rotor and the fixed casing.

Advantages

1. The pump is self-priming.

2. They produce a uniform discharge with negligible pulsations.

3. The vanes are self-compensating for wear. Slip is minimal.

4. Pumping in either direction is possible on some spring-loaded vane pumps.

5. No one-way valves at inlet and discharge are required on spring-loaded vane pumps.

6. Liquids containing vapours and gases can be handled.

Disadvantages

1. The pump cannot operate against a closed discharge without causing serious damage. Pressure relief valves are needed or the drive unit must be fitted with an overload cut-out facility.

2. These pumps should not be used on products containing abrasive materials.

3. Shaft seals are required.

4. These pumps are relatively more difficult to clean. A flexible vane pump (see Fig. 10, Appendix III) is available which is much easier to clean.

5. Vane pumps are not normally suited to pressure heads greater than about 50 psi (3.42×10^5 N/m^2).

5. Screw Pumps (see Fig. 11, Appendix III)

Many screw-type pumps are currently marketed. Single two and three stage screw pumps are manufactured with various designs of rotors. One type of screw pump widely used in the food industry has a helical screw rotor which revolves in a flexible stator. The rotor and stator are shaped such that cavities formed at the suction or inlet side move towards the discharge or outlet end of the pump as the helical screw rotates. The creation of a cavity at the inlet produces a partial vacuum which induces the product to flow into the pump. The product is then carried forward to the discharge by the screw action.

Advantages

1. These pumps are self-priming.

2. They produce a uniform discharge with negligible pulsations.

3. A wide range of liquid viscosities can be handled.

4. Liquids containing substantial amounts of suspended solids, and also those containing vapour and gases can be handled.

5. A useful pump for shear-sensitive products.

6. No check valves are required.

7. These pumps can be easily dismantled for cleaning.

8. These pumps can be used for many food product transfer duties.

Disadvantages

1. These pumps tend to be bulky and heavy.

2. They are subject to relatively large changes in capacity with variations in viscosity and discharge pressure.

3. They are damaged if run dry for relatively short periods.

4. Shaft seals are required.

6. Diaphragm Pumps (see Figs 13, 14 and 15, Appendix III)

Diaphragm pumps can operate either mechanically or hydraulically. The movement of the flexible diaphragm induces product flow. In fluid-driven diaphragm pumps, the fluid transmits motion from a reciprocating piston to the diaphragm. In mechanically-driven pumps the motion from a reciprocating piston is directly transmitted to the diaphragm.

There are two principal types of diaphragm pump commercially available, a plain diaphragm and a tubular diaphragm.

Advantages

1. These pumps are usually self-priming.

2. Both the fluid and mechanical driven units give a pumping rate which is substantially independent of discharge pressure.

3. These pumps can handle liquids containing vapours and gases.

4. Liquids containing solids can be pumped.

5. No seals are required.

6. The only moving parts in contact with process material are the flexible diaphragm and the inlet and outlet one-way valves.

7. Pump cleaning is relatively easy.

Disadvantages

1. These pumps have a pulsating discharge.

2. One-way valves are required which can limit the size of the solids pumped.

3. They are not suitable for high pressure applications.

4. The life of the diaphragm is considerably reduced when the product, cleaning fluids and sterilisation fluid temperatures are above 90°C.

7. Peristaltic Pumps (see Fig. 12, Appendix III)

A peristaltic pump has a rotor with attached rollers. A flexible tube passes through the fixed casing of the pump. As the rotor revolves, the rollers press and run on the flexible tube exerting a squeegee action which induces product flow within the tube. The flow rate is proportional to the bore size and the rotor speed.

Advantages

1. These pumps are self-priming.

2. They can pump in either direction.

3. The delivery rate can be increased by increasing the tube diameter and the roller speed.

4. Liquids containing vapours and gases can be handled.

5. Shear-sensitive materials can be pumped.

6. No check valves are required.

7. No shaft seals are required.

8. These pumps are very hygienic since the product is completely isolated from the prime moving parts.

9. The tube can be cleaned easily and can be easily replaced by unskilled labour.

Disadvantages

1. These pumps are relatively low in capacity.

2. As the flexible tube bore size is increased lower operating discharge pressure limits are imposed.

3. Tube wear can be excessive. Frequent replacement increases running costs.

METHODS OF CLEANING PUMPS

Most food companies adopt cleaning procedures and sequences based on experience gained on their production plant manufacturing a specific product.

Most positive displacement pumps are stripped down and cleaned manually.

A few pumps are cleaned in-place using, in general, the following cleaning sequence:

Product Purge and Rinse

Production is stopped and the plant is either purged with air and then rinsed with water or merely rinsed with water alone. The time for this operation is variable but usually falls within the range ½–1 hour. Some companies claim that one to three times the plant volume of water is all that is necessary to remove the majority of the product from the system.

Detergent

A hot caustic solution at a temperature of 60 to 80°C is then used to clean the plant. This can be a proprietary detergent or merely a dilute solution of sodium hydroxide (usually ½ to 2% NaOH by weight). The duration is variable depending on plant and product but usually falls within the range ¼ to 1 hour.

Water Rinse

This is then followed by a cold or hot water rinse for a period of usually ¼ to ½ hour. Some companies terminate their cleaning cycle at this point.

Acid Clean

An acid clean is necessary on some plants, which is dependent on the nature of the soil (e.g. mineral salt deposition or 'stone').

Rinse

The acid clean is then followed by a cold or hot water rinse.

Sanitisation

A chlorine based sanitiser (e.g. sodium hypochlorite solution) is very often used at concentrations between 200–300 mg/l of available chlorine. Quaternary ammonium compound formulations are also used which have combined detergent and disinfectant properties.

Final Rinse

This is followed by a final rinse with clean potable water. Some plants are then allowed to drain dry.

Some food companies use steam or hot water to disinfect the plant after cleaning. Hot water temperatures in excess of 80°C for around 2 minutes duration are used.

Some plants are required to operate under aseptic conditions and it is necessary to sterilise the plant before food production. Plant sterilisation implies total destruction of microbial vegetative and spore forms. This is usually accomplished by either steam or high pressure hot water at temperatures of 130 to 150°C for periods of ½ to 1 hour duration.

METHODS USED TO ASSESS CLEANABILITY

Product Examination

The main method is by regular microbiological monitoring of the product. The plant is critically examined if the total viable microbial load of the product is above the accepted standard. Analysis of the product for micro-organisms, foreign bodies and taints may give information on the efficacy of cleaning.

Visual Examination of Plant

A visual examination of food contact surface is all that is necessary in certain cases. This only gives an indication of gross soil removal.

Microbiological Examination of Surfaces

Swab, rinse and contact methods are used in the food industry often on a routine basis.

Standard procedures are described in documents issued by MAFF[3] specifically for the dairy industry.

The dairy standards for the efficacy of cleaning are followed by many food companies.

For example, when the swabbing technique is used the results are expressed as "colony count per square foot".

The interpretation of the results is outlined in the following table taken from a document issued by MAFF, "The swab method for examination of milk plant", Form No. C195/TPY[3].

Colony count per square foot	Classification
Not more than 5,000	Satisfactory (S)
5,000 – 25,000	Fairly satisfactory (FS)
Over 25,000	Unsatisfactory (US)

Some companies have their own standards based on past experience. One such company uses:

Colony count per square foot	Classification
Not more than 360	Excellent clean
360 – 1,800	Very good clean
1,800 – 18,000	Good clean
18,000 – 25,000	Acceptable clean
Over 25,000	Unacceptable clean

Another company claim a colony count of 100 per square inch and below as clean and above 100 per square inch as unsatisfactory.

Coliform levels of 10 per square inch and below are acceptable and above 10 per square inch are unacceptable.

PROBLEMS ASSOCIATED WITH CLEANING

1. Skilled labour is required to strip down and re-assemble many positive displacement pumps when they are manually cleaned. Companies want to use the semi-skilled cleaning labour force instead of experienced fitters.

2. High temperature cleaning fluids sometimes cause the rubber components in a pump to swell.

3. Rubber and plastic surfaces can crack when hot fluids are pumped due to the low thermal conductivities of these materials. Products embedded in these cracks are difficult to remove by both cleaning in-place (C.I.P.) and manual cleaning methods. The defective rubber component is replaced, which is costly.

4. When a pump is isolated for manual cleaning dead pockets on a by-pass are difficult to avoid and subsequently difficult to clean.

5. When some pumps are cleaned in-place with high temperature cleaning fluids a greater rotor and stator clearance is needed to avoid fouling due to uneven component expansion. This leads to increased slip when pumping process fluids at a lower temperature.

6. The viscosities of cleaning fluids are low compared with many food products and the positive pumping characteristics are not maintained when rotor and stator clearances have been increased for other reasons (e.g. when hot water or steam sterilisation is needed). Two pumps are sometimes required for a complete process line, one for C.I.P. and the other for production.

7. Fixed speed positive pumps often do not have the required capacity to maintain the desired cleaning fluid velocities in the rest of the plant.

8. The maximum speed of variable speed pumps is often not sufficient to maintain the desired cleaning fluid velocities in the rest of the plant.

9. Taints can be picked up on the rubber and plastic components from the cleaning fluids which can subsequently contaminate the product.

10. The time taken to clean some pumps manually is longer than the time to clean the rest of the plant.

11. Product can still remain in packed glands and mechanical seals following C.I.P. and even manual cleaning procedures.

12. Most proprietary positive pumps have crevices and dead pockets which are difficult to clean by C.I.P. and even manual cleaning methods.

13. Product sometimes passes beyond piston seals and rings which is difficult to see and clean in many piston pumps.

14. Positive pumps for systems where high rate aseptic product transport is needed are not readily available at present. Positive pump sterilisation causes casting and rotor fouling due to uneven component expansion when steam or water is used at temperatures in excess of 130°C.

15. Many positive pumps are fitted with a by-pass line on the discharge. A pressure relief valve fitted into this line protects the pump when the maximum operational discharge pressure is exceeded. This line is difficult to clean and some pump users favour a bursting disc which is much easier to clean.

16. The one-way valves located up stream and down stream of a piston and diaphragm pump, for example, are difficult to clean in-place. Manual cleaning is necessary. Skilled fitters using special tools are often needed.

17. Manual re-assembly of pumps after cleaning may contribute significantly to the microbial load on pump surfaces.

MECHANICAL PROBLEMS

1. Rotors can foul on the casing when high temperature fluids are pumped. The rotors are sometimes skimmed to overcome this problem.

2. Rubber components can crack when subjected to many heat cycles. Pieces can break off ending up in the product.

3. Rubber and plastic components can be abraded when there are hard gritty materials in the product. Gritty products can also damage metal surfaces causing pitting and erosion.

4. Hard product constituents can tend to force rotors apart resulting in excessive bearing wear. Once the bearings are defective rotor damage usually follows.

5. Rotors on some pumps can come undone if not tightened properly. The unscrewing action can be assisted by pump operation.

6. Gland, seal, and shaft wear occurs when abrasive products are pumped.

7. The assembly and dismantling of some pumps are difficult requiring experienced fitters, very often using special tools, instead of unskilled labour.

8. The materials of construction can be a problem if they are not compatible with the product (e.g. phosphor bronze picks up when in contact with stainless steel).

9. Seal life is too short. Seals often have to operate under very arduous conditions (e.g. wide temperature cycles, continuous operation for long periods, fluctuating pressure cycles).

10. Some pumps are instantly damaged if operated dry (i.e. without a product or liquid lubricant).

11. When some pumps are run backwards for a few revolutions, for example when the correct motor direction is being established, the seal springs unwind.

12. Most positive pumps are severely damaged when operated against a closed discharge. Overload protection in the form of bursting discs and pressure relief valves are used to overcome this.

13. It is more difficult to align pump components having a fixed dimension (e.g. gear wheels) with very small clearances between the parts.

14. Vane pumps are unsuitable for abrasive products but the vanes are self-compensating for wear providing it is not excessive.

15. Under certain conditions it may be necessary to use a large pump and run it at low speed in an attempt to prolong the life of components in contact with moving parts (e.g. seals, glands, bearing, rotor, etc.).

16. Special wide bore entry throats may be needed on pumps when very high viscosity fluids are transported.

PROCESS PROBLEMS

1. The self-priming capabilities are considerably reduced when the clearances between the rotor and stator or case are increased to correct other deficiencies. Suction lift is also reduced.

2. Air may be drawn in worn shaft seals causing reduced throughputs. Small amounts of air passing through slightly worn seals are difficult to detect and may cause product damage.

3. Shear-sensitive food products may be damaged in pumps having narrow passages (e.g. high fluid velocities through one-way inlet and outlet valves on piston pumps). A large pump running at low speed may be necessary.

4. Pump throughput may change with a change in product viscosity and discharge pressure, particularly when the pump clearances are large allowing more 'slip'.

5. Lobe pumps have more of a pulsed flow than gear pumps. An increase in the number of lobes reduces the pulsation. The greater the number of lobes the smaller the particulates it is able to pump without damage.

6. There is frequently a need for two pumps, one to pump water-like products and cleaning fluids and one to pump viscous food products.

7. Few positive pumps can be sterilised with water or steam at temperatures in excess of 130°C. Most of the rubbers and plastics currently available are not suitable under these conditions. Rotor and stator fouling can occur due to uneven component expansion. High nickel alloys have been used with some success.

8. Small bore peristaltic pumps (i.e. up to about 2.0×10^{-2} m diameter) are suitable for steam sterilisation but as the bore size increases beyond this the tube material is not strong enough to withstand the pressures required.

9. It may be necessary to duplicate pumps for use on a continuous process so that one pump can be refurbished whilst the other is used on production.

10. Most positive pumps are not truly positive especially when clearances have been made larger to correct other deficiencies.

11. The discharge of a single piston or plunger type pump pulsates. A more even flow is achieved using a double acting stroke or a number of cylinders in parallel with piston or plunger operating out of phase.

FEATURES OF AN IDEAL POSITIVE DISPLACEMENT PUMP FOR USE IN THE FOOD INDUSTRY

a) General Requirements

1. The pump must be easily dismantled and assembled by unskilled labour. The use of special tools must be avoided.

2. The discharge rate must be constant (i.e. not a pulsed flow). The throughput must also be independent of product viscosity and outlet pressure.

3. Ideally the pump should have no rotary seals. If this is unavoidable the seal should be designed such that (a), no product flows into the seal or, (b), the product flowing through the seal does not, in any way, contaminate the fluids pumped.

4. The pump must be capable of pumping all types of fluids in a totally positive manner (i.e. water, cleaning fluids, products containing fragile particulate solids of nominal dimension 20 mm, products containing gritty and abrasive materials).

5. The pump should not have crevices or dead pockets where product can accumulate. Crevices must not be allowed to form in any component part during use.

6. Ideally sterilisation using pressurised water or steam up to a temperature of 150°C should be possible without adversely affecting the pumping performance.

7. The material of construction of the component parts must be inert to the cleaning fluids as well as the food products pumped.

8. Protection devices must be included in the pump design to prevent damage to both the pump and the product where necessary.

9. The pump must be designed for cleaning in-place. The pump throughput using cleaning fluids must be such that the desired cleaning fluid velocities in the rest of the plant are achieved.

10. Paints used for external finish must be inert to cleaning fluids and products and must contain no constituents harmful to health.

b) Specific Requirements

1. The range of throughputs required by the food industry is 0–10,000 g/h (0–1.27 x 10^{-2} m^3/s). More specifically 0–400 g/h (0–5.07 x 10^{-4} m^3/s) for metering and transfer duties and 0–4,000 g/h (0–5.07 x 10^{-3} m^3/s) for ring mains.

2. The majority of food companies require pumps capable of an outlet pressure of up to 200 psig (1.47 x 10^6 N/m^2). One company requires up to 1,000 psig (6.95 x 10^6 N/m^2).

3. The pump must be capable of operating efficiently over a temperature range from ambient to 150°C.

4. Pumps should be supported on a crevice-free support structure. A skeleton frame was suggested by one company to make external cleaning easier.

CONCLUSIONS

The main disadvantages of many of the conventionally designed positive displacement pumps stem from the necessity to use dissimilar materials of construction for the pump elements and the need to employ glands and valves.

The food industry needs a new positive displacement pump with the following specification:

(a) Constant steady discharge rate up to 10,000 g/h (1.27 x 10^{-2} m^3/s).

(b) Discharge pressure up to 200 psig (1.47 x 10^6 N/m^2).

(c) Improved hygienic features.

(d) Easy to dismantle and assemble.

(e) Capable of pumping:

(i) viscous and water-like products at a predictable rate.

(ii) products which are shear-sensitive, without damage.

(iii) abrasive materials.

(f) Reliable under arduous operating conditions i.e.:

(i) fluctuating temperatures over range 0–150°C.

(ii) fluctuating pressure over range 0–200 psig ($0–1.47 \times 10^6$ N/m^2).

Quite clearly, many food manufacturers are dissatisfied with the operational and mechanical features of the many positive displacement pumps currently available. It is therefore recommended that the Food R.A. contact pump manufacturers to discuss ways and means of designing a pump or a transfer system to meet the food process engineers' requirements.

REFERENCES

[1] Joint Technical Committee FMF/FMA. (1969). "Hygienic design of food plant." A guide to good practice with particular reference to the design of tanks, pumps and pipework. p. 12.

[2] Joint Technical Committee FMF/FMA. (1969). "Hygienic design of food plant." A guide to good practice with particular reference to the design of tanks, pumps and pipework. p. 22.

[3] Ministry of Agriculture, Fisheries and Food. (1945). "The swab method for examination of milk plant." Form No. C195/TPY.

Laboratories of the British Food Manufacturing Industries Research Association, Randalls Road, Leatherhead, Surrey.

June, 1979

APPENDIX I

Seven basic principles for judging hygienic design of pumps, pipelines, valves, tanks and vessel taken from a brief code of practice produced by the Food Manufacturers' Federation and the Food Machinery Association's Joint Technical Committee in 1969 are as follows:

1. All surfaces in contact with food must be inert to the food under the conditions of use and must not migrate to or be absorbed by the food.

2. All surfaces in contact with food must be smooth and non-porous so that tiny particles of food, bacteria or insect eggs are not caught in microscopic surface crevices and become difficult to dislodge, thus becoming a potential source of contamination.

3. All surfaces in contact with the food must be visible for inspection, or the equipment must be readily dis-assembled for inspection, or it must be demonstrated that routine cleaning procedures eliminate the possibility of contamination from bacteria or insects.

4. All surfaces in contact with food must be readily accessible for manual cleaning, or if not readily accessible, then readily dis-assembled for manual cleaning or if cleaning-in-place techniques are used it must be demonstrated that the results achieved without dis-assembly are the equivalent of those obtained with dis-assembly and manual cleaning.

5. All interior surfaces in contact with food must be so arranged that the equipment is self-emptying or self-draining.

6. Equipment must be so designed as to protect the contents from external contamination.

7. The exterior or non-product contact surfaces should be arranged to prevent harbouring of soils, bacteria or pests in and on the equipment itself as well as its contact with other equipment, floors, walls or hanging supports.

APPENDIX II

Guidelines specifically for use in hygienic pump design issued by FMF and FMA:

1. Passage shapes should be smooth, sharp changes in cross-section should be avoided and dead spaces or turbulence-promoting features minimised.

2. When cleaning-in-place is intended this will be facilitated by meeting the above criteria. Otherwise ease of dismantling is essential to allow access for cleaning all surfaces which contact food material. The number of ports should be a minimal.

3. Parts requiring periodic replacement should be easily replaceable and designed so that they cannot be wrongly assembled. Joints and seals should be so designed that leak-proof assembly is most easily achieved with the correct components without recourse to sealing compounds.

4. Screw threads in contact with food material should be avoided, e.g. by retaining impellors with cap nut and gasket. Where unavoidable, threads should be male, coarse and shallow, preferably not less than 60° nor more than 8 t.p.i. (3.2×10^{-3} m pitch).

5. Location of moving components should be by flats rather than by keyways or splines.

6. Clamp rings or bayonet couplings of smooth 'clean' shape are preferable to bolts as fastening for pump bodies.

7. Pumps should be so designed as to be readily emptied of product. In the case of non-positive pumps adequate clearances and appropriate arrangement of branches, internal ports and components should permit self-draining.

8. Positive pumps should be either similarly self-draining or capable of being operated so as to be self-emptying.

9. Pump overload protection shouid not involve venting to atmosphere or recirculation of process material at the pump. Where this is unavoidable the design with reference to the foregoing requirements is advisable.

10. Bearings should be located outside the product zone and be of sealed or self-lubricating type.

11. Wherever possible, shaft seals should be of the mechanical type and accessible for inspection adjustment and maintenance.

12. Any leakage which might occur should be readily visible and should be to the open (i.e. not into closed spaces such as motor casings).

13. All external parts should be easily cleanable and capable of withstanding frequent hosing or such other cleaning down procedures as are commonly used in the intended location.

APPENDIX III

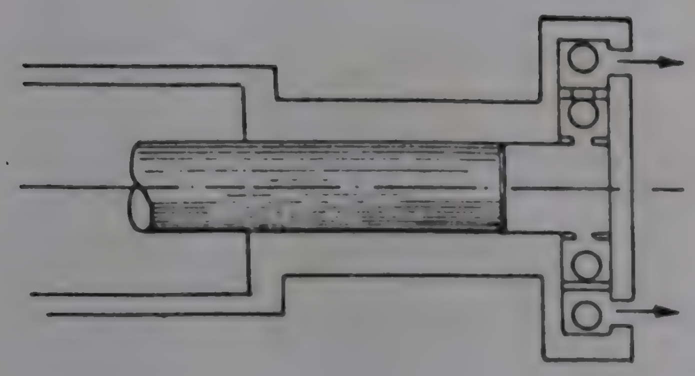

Fig. 1. Plunger pump showing one-way valves

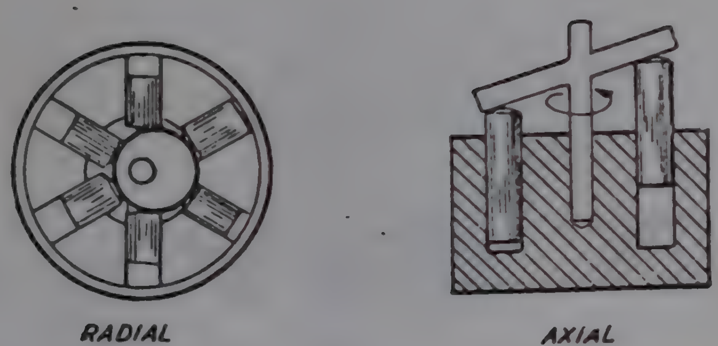

Fig. 2. Stationary cylinder block rotary piston pumps

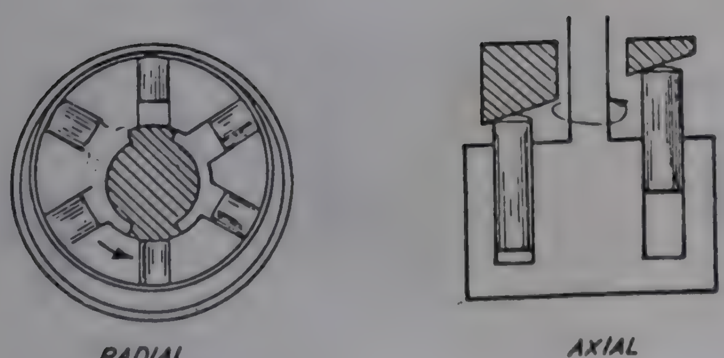

Fig. 3. Rotating cylinder block rotary piston pumps

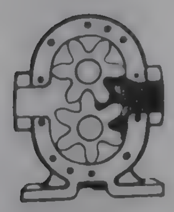

Fig. 4. External gear pump

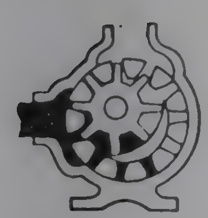

Fig. 5. Internal gear pump

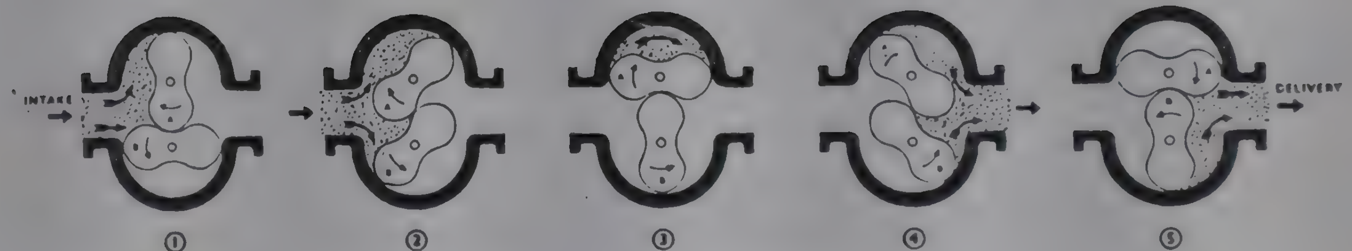

Fig. 6. Two-lobe rotor pump

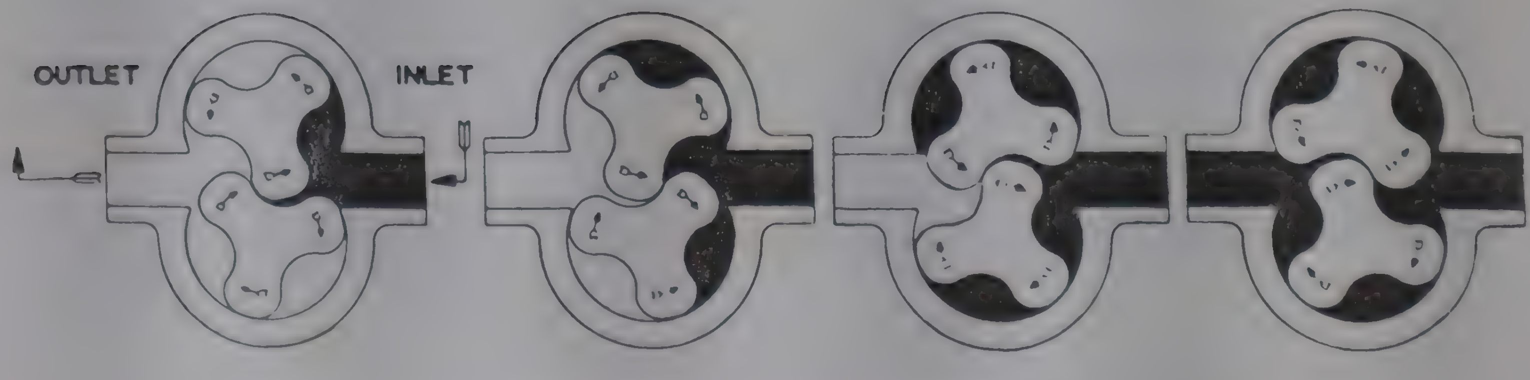

Fig. 7. Three-lobe rotor pump

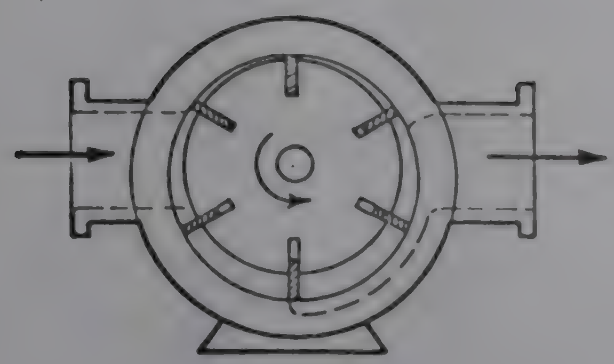

Fig. 8. Sliding vane pump

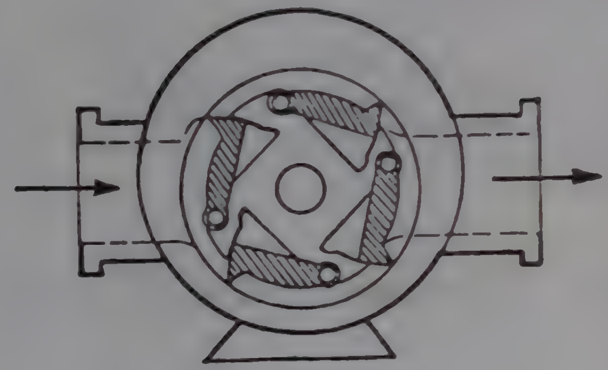

Fig. 9. Swinging vane pump

Fig. 10. Flexible vane pump

A – Throat entry
B – Gland
C – Auger conveyor
D – Drive yoke
E – Stator
F – Rotor

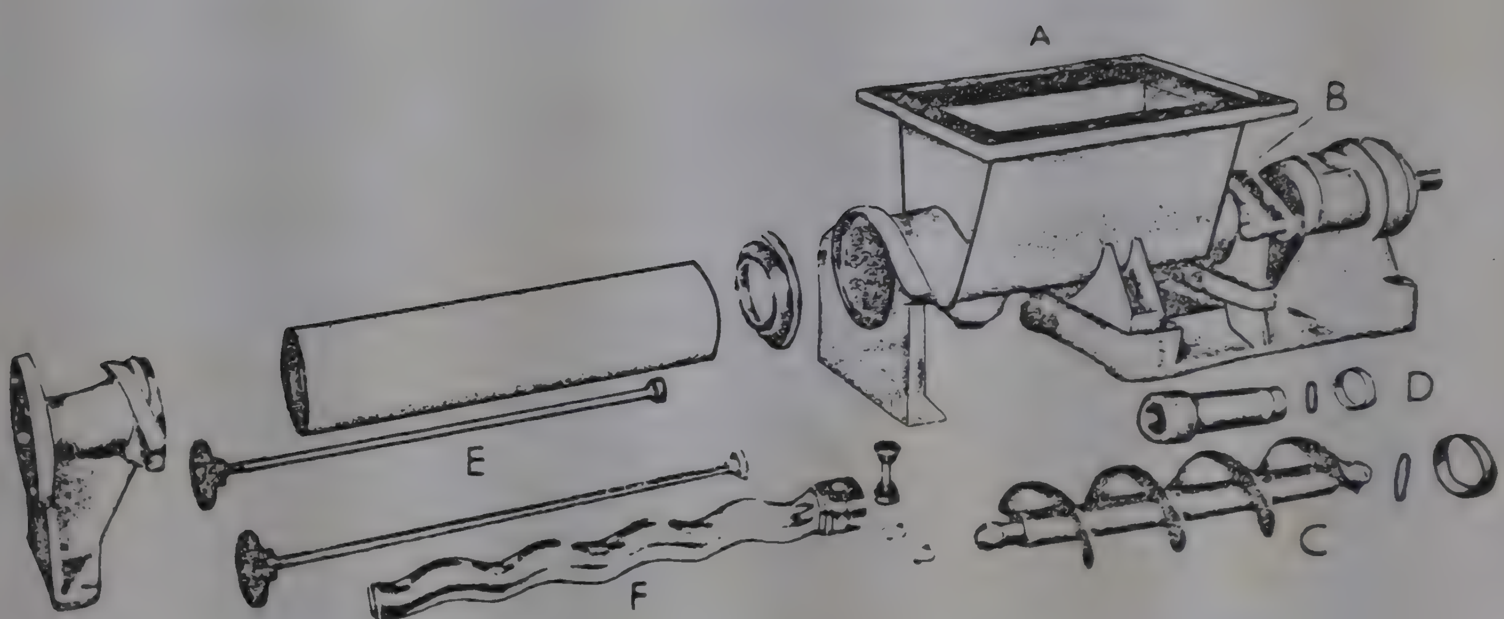

Fig. 11. Wide throat screw pump (mono)

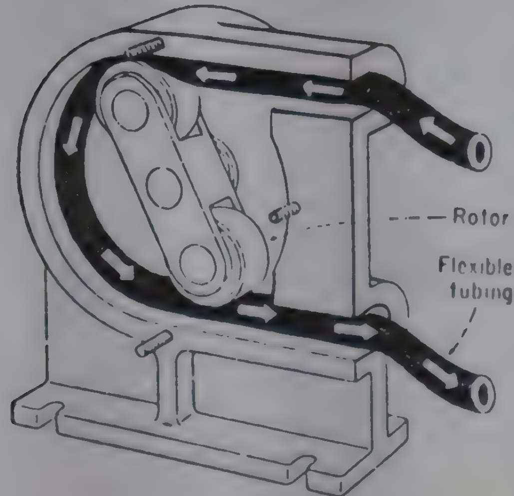

Fig. 12. Peristaltic pump

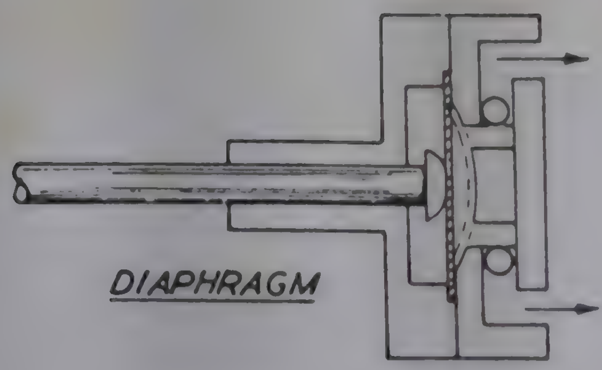

Fig. 13. Direct acting diaphragm pump

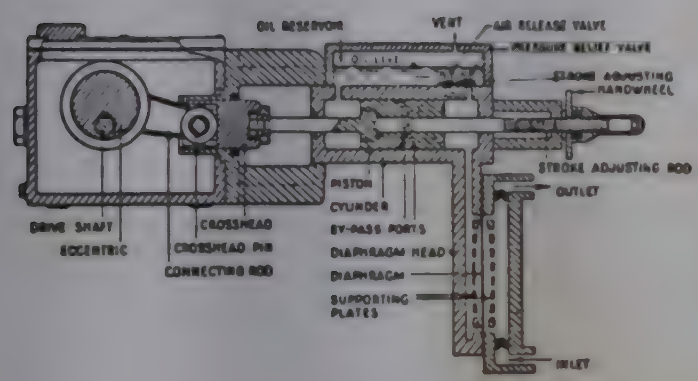

Fig. 14. Hydraulically operated piston-diaphragm pump (Wallace & Tiernan)

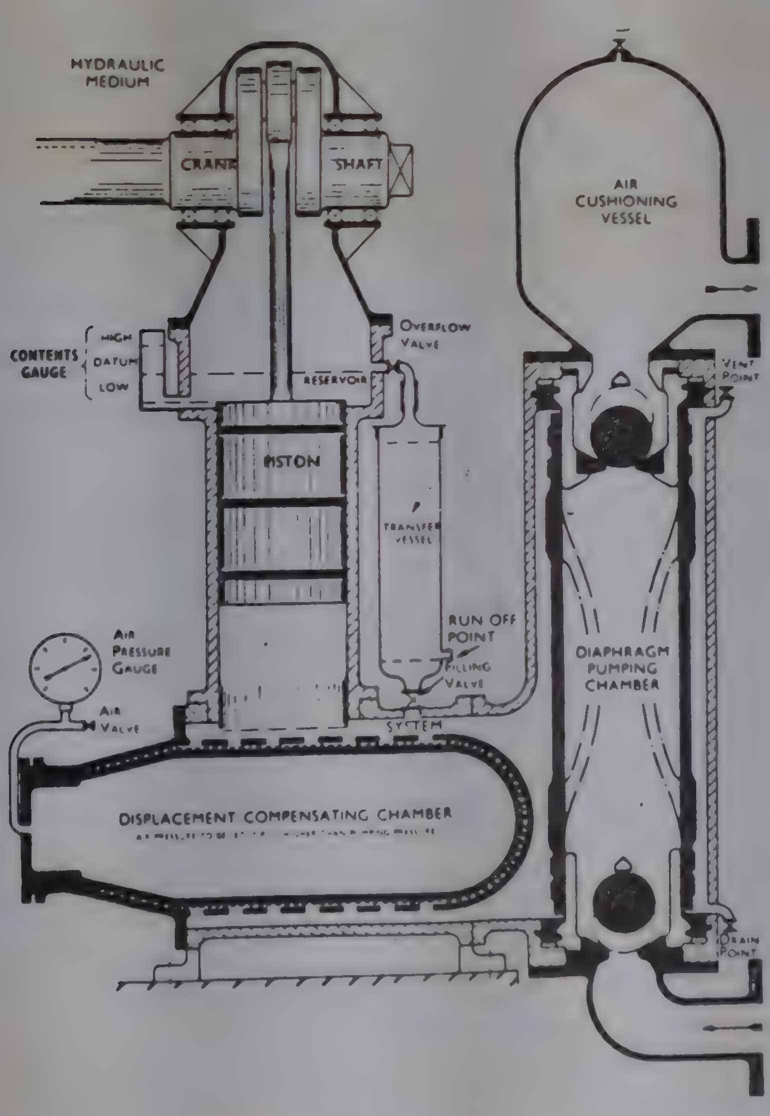

Fig. 15. Tubular diaphragm pump (Merrill)

LEATHERHEAD
FOOD R.A.

HYGIENIC PUMPS FOR FOOD MANUFACTURE

R. DARLINGTON, B.Sc.

SCIENTIFIC & TECHNICAL SURVEYS No. 111

JUNE, 1979